Int. J. Engng Ed. Vol. 00, No. 0, pp. 1–10, 2007
Printed in Great Britain.

0949-149X/91 $3.00+0.00

ED-WAVE: an Educational Software for Training on Wastewater Technologies Using Virtual Application Sites*

PANAGIOTA PARASKEVA,[1] EVAN DIAMADOPOULOS,[1] MALINI BALAKRISHNAN,[2] VIDYA S. BATRA,[2] ANDRZEJ KRASLAWSKI, [3] YURI AVRAMENKO,[3] NIRANJANIE RATNAYAKE,[4] BUDHIKKA GUNAWARRDANA,[4] DIEGO GUTIERREZ,[5] OSCAR ANSON[5] and THUMRONGRUT MUNGCHAROEN[6]

[1] Department of Environmental Engineering, Technical University of Crete, Polytechneioupoli, Kounoupidiana, 73 100. Chania, Greece. E-mail: tparaskeva@dpem.tuc.gr
[2] TERI School of Advanced Studies. [3] Lappeenranta University of Technology. [4] University of Moratuwa. [5] University of Zaragoza. [6] Kasetsart University

ED-WAVE is an electronic learning tool created under the Asia-Link Programme, a programme dedicated to the promotion of regional and multilateral networking between higher education institutions in European Union (EU) member states and South-East Asia and China. ED-WAVE has been developed by a consortium of three Asian and three European universities. It is an innovative product of high interdisciplinary action providing theoretical information, worked out examples, computer graphics, case study database and case base reasoning in the field of wastewater treatment and water reclamation. ED-WAVE aims also to provide a sustainable platform for ongoing learning on technologies improving water quality and efficiency by exposing the target groups to real-life applications through virtual industrial and municipal environments. The target groups involve students at undergraduate and graduate level, educators and young professionals working in water and related industries. The tool is going to be used in select courses in each institution as part of curriculum development.

Keywords: educational software; environmental engineering education; wastewater technologies; wastewater treatment animations

INTRODUCTION

SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT have, in the last decade, become a key concept in most aspects of life, of which education is an integral part. Methodologies for protecting environmental quality and ecosystems while supporting economic growth and development are issues that until recently were not included in traditional curricula [1, 2]. In recent years environmental education has become an important part of many academic curricula in several faculties from earth sciences to business and law. Naturally the field of engineering ought to play a pioneer role in offering renewed courses, as engineers are responsible for safeguarding both the environment and human health, by means of design, construction, production and inspection. While approaches towards effective waste management, such as waste elimination at source, renewable energy, life cycle assessment and cleaner production technology have altered radically university curricula, traditional pollution control and technologies for clean-up processes remain an integral part of engineering education and have a lot to offer in environmental preservation and economic development [3–6]. In environmental engineering curricula, in-depth understanding, appropriate design and practical experience are essential elements in the dynamics of sustainability, leading to proper use of available technology, improvement and replacement of existing schemes, appreciation of modern technologies which all help address the issue of water recycle and reuse and water preservation—chapters of great importance in the sustainability book. Moreover, in developing countries of South-East Asia great issues of water shortage, water quality deterioration and limited or non-existent wastewater treatment especially in small and medium enterprises have made technologies for efficient water use a priority sector[7].

Several colleges/universities in the target countries offer undergraduate and graduate programmes in environmental engineering/ management/ science. The curricula are, however, typically academic and not geared to real-life applications. Within the workforce, there is insufficient awareness among most industries, technical service providers and environment practitioners regarding the range of wastewater treatment options that can be adopted and tailored to suit a given enterprise. In

* Accepted 28 August 2007.

developing countries, technology is often imported but rarely adapted to suit local conditions. Further, the focus is on hardware, ignoring factors like skills and training. In view of the alarming water situation, it is imperative to incorporate training on water-use efficiency as a part of an existing curriculum, particularly using examples from real life, with emphasis on regional cases.

Because of changing environmental requirements, engineers are required to work in interdisciplinary environments bridging the fields of science and society. One such popular science, computer science, has created new tools for education, visualization and practical experience, for example, 'simulation', in a rapid and cost- effective way, where the student has fast and easy access to information and is allowed to experiment in design by trying and testing several engineering scenarios. Alienation from traditional learning, compromise of critical ability and thought and loss of traditional engineering skills, are some of the counter-arguments against computer-based education. It is left to the scope of universities and to individual tutors to find a balance between traditional and computer-based learning, taking into consideration current situations and opportunities, but also local needs and requirements.

In practically every aspect of engineering and science, computer-based tools are being developed to aid students and professionals in learning through modelling, simulation and interactive software. The Internet has been utilized as the ideal medium to create platforms for students to use for its wide availability but also multimedia tools and computer graphics-based software, which are developed to enhance the teaching process. The students in engineering degree courses usually have difficulties when attempting to understand some concepts, even the basic ones. And the key is when they express their frustration—'I don't see it'. Here is where computer graphics and multimedia come into play, expressing in a visual way these concepts and trying to help engineering students develop the necessary skills to carry out creative design based on abstract thinking. But the users of these educational tools usually need to be helped to understand the methods of presentation of specific multimedia technology, where text, sound, pictures, video, 3D and interaction can be combined. In environmental engineering, laboratory simulations offer interactive teaching and learning through the web with virtual instrumentation and simulations of pollutant transfer and transformation pathways in air, water or soil [8, 9]. In wastewater treatment there are several commercial packages available (STOAT, GPS-X, CapdetWorks, Process Advisor, SASS series, SIMBA series, etc.), targeting mostly professionals working in the water industry, providing expert system tools for use in the design of wastewater treatment plants, hydraulics, mass transfer modelling, troubleshooting, etc. Other attempts in academia, offer a virtual tour of a specific wastewater treatment plant explaining the technologies applied [10]. Since much is to be gained from users experimenting in design and operation, spreadsheet models have also been adapted for teaching students resulting in their increased capacity to appreciate and tackle a problem [11, 12].

METHODOLOGY

In a modern environmental engineering or related curriculum, the target of courses dealing with wastewater and wastewater reclamation technology should be able to offer to the student the following:

- Assessment of water use and water consumption patterns.
- Theoretical knowledge of available technologies for wastewater treatment and reclamation.
- Practical understanding of the mechanisms involved in unit processes.
- The ability of designing a simple unit operation based on practical information.
- The possibility of accessing real industrial data on current practices and results.
- The ability to check simple problem-solving scenarios.
- The information to problem-solution practices.
- Applied techniques in 'good housekeeping' and wastewater minimization in regional industries of the target countries.

This specific project aims also to offer a broader opportunity for people not familiar with wastewater treatment technologies (young practitioners, senior policy makers) to familiarize themselves with current technologies and get the benefit of real life applications specially in the target developing countries. This current highly innovative project combines the elements of traditional engineering education and modern computer-based tools by providing an IT-based tool combining theoretical information, virtual demonstration of technologies, spreadsheet models, a small database of case studies in select municipal and industrial sector and a basic case base reasoning system allowing the user to access the most suitable treatment sequence or create his/her own logical one, supplemented by printed material and regular coursework on water usage, technologies for efficient water and energy use, in municipal and industrial processes as well as process selection and modelling in wastewater treatment.

Target groups

The primary target group for this tool are students and academics. The tool is by no means a substitute for a proper textbook and, in any case, will be supplemented by appropriate reading material and coursework.

For maximum benefit to be attained from the project, three target groups of direct beneficiaries were focused upon: educators in colleges and universities, students enrolled in appropriate programmes, e.g. environmental engineering / sciences / management, natural resources management, chemical and civil engineering; and environmental practitioners and institutions including those conserving and protecting world heritage natural sites.

Educators and students in universities offering programmes in environmental engineering / sciences / management were selected as the primary target group because of the need to narrow the gap between theory and practice in this sector. Existing curricula in colleges / universities in the partner countries, especially in Asia, suffer from an absence of hands-on practical training, owing to the expense involved in developing laboratory infrastructure with appropriate pilot set-ups. This leads to an inability to correlate and apply academic learning to real-life full-scale applications. ED-WAVE was produced by a consortium of six partners with great diversity in fields of expertise, in order to create an interdisciplinary project flexible to be incorporated in the curricula of each university.

Universities participating in the project

The partner universities are:

- TERI School of Advanced Studies (TERI, India), engaged in the broad area of clean technologies to achieve energy efficiency and minimize adverse environmental impacts, also offering postgraduate courses;
- Department of Environmental Engineering of the Technical University of Crete (TUC, Greece), involved in the development and application of technologies for the appropriate management and treatment of water, wastewater and solid wastes, also offering undergraduate and postgraduate courses;
- Department of Chemical Technology of Lappeenranta University of Technology (LUT, Finland) focusing on the development of knowledge-based systems and case-based reasoning and soft simulation of various systems, also offering undergraduate and postgraduate courses;
- Advanced Computer Graphic Group of the University of Zaragoza (UNIZAR, Spain) focusing on research, innovation, development and teaching in all computer graphics related fields;
- Civil Engineering department of the University of Moratuwa (MRT, Sri Lanka), engaged in teaching and research in water supply, wastewater management and collection, environmental impact assessment as well as monitoring and testing for water quality;
- Department of Chemical Engineering of the Kasetsart University (KU, Thailand) specializing in research and training in the fields of cleaner technology, life cycle assessment and eco-design.

Targeted courses and curricula

The curricula addressed are those of environmental engineering, natural resources engineering, chemical engineering, environmental technology and similar faculties. The primary target of the programme was to implement the software and the associated printed material in the following courses:

1. Technologies for efficient water use. To be incorporated in the Masters in Natural Resources Management at TERI-School, in the graduate programme of Environmental Engineering at TUC, in the graduate programme of Environmental Engineering and Management, Environmental Management, Water Resources Engineering and Management and Urban Planning at MRT.
2. Process selection & modelling of wastewater treatment. To be incorporated in the graduate programme in Chemical Technology at LUT.
3. Efficient water & energy use in pulp and paper industry. To be incorporated in graduate programmes in Chemical Engineering, Environmental and Water Resource Engineering at KU.
4. Computer graphics and new technologies in environment education. To be incorporated in Masters Programmes in Environmental Engineering and Environmental Techniques for Enterprises at UNIZAR.

Apart from these specific courses, the tool can be a part of already existing courses in the universities orientated in the environment area. The tutor has to determine whether he will use part of the software or the software as a whole depending on the level of the students and the relevance to the course. Such courses include:

1. Wastewater treatment design courses offered in the final year of environmental engineering departments.
2. Physical, chemical and biological wastewater treatment methods. Offered as separate or combined courses in several undergraduate schools and in masters programmes in related faculties.

Further, the tool and the print material can be used for short courses for students or professionals. For instance, TERI School is preparing a four-week Certificate Course in Environmental Management for industries where the above contents will be used.

RESULTS

Description of the education tool

The education tool is a package of computer applications supplemented by data files, animations and demonstrations. The system consists of four modules and one supplementary:

1. Reference Library (RL) a structured e-book with theoretical knowledge on wastewater unit operation as well as training examples;
2. Case study Manager (CM), with case studies from real life applications;
3. Process Builder (PB) serves to construct a full treatment sequence from basic unit operations presented as blocks;
4. Treatment Adviser (TA) assists in problem-solving exercises;
5. In addition a 'glossary' section gives the user brief information about terminology encountered in the software.

The package can be divided into a theoretical part (RL, CM) and a practical part (PB, TA and models included in the RL). The components support the complete training activity from presentation to problem solving and design. All materials are presented with instructed thematic ways and navigation is similar to World Wide Web browsing. Novel techniques such as case-base reasoning and stream-set analysis are implemented in the components of the tool. The four tool modules in more detail are as follows:

Reference Library (RL): This module assists the tutor in formulating the presentation of select technologies and in coursework. It also provides the user with a concise form of the traditional book—with text, pictures and problems—which virtually walks the user through each technology. The RL is not a substitute for textbooks though. It provides concise information and technical details but urges the user to consult further published work through references. The module provides the user with a comprehensive overview of 21 processes used for wastewater treatment. Each process consists of the following seven sections:

1. The description window, where a general description, an overview, of the treatment technology and its purpose is presented.
2. The theoretical background section; this section is based on textbooks and published papers and provides theoretical information about the principle of each technology as well as an analysis of the elements of each unit operation. Where appropriate, mass and energy balances around unit operations are provided. The user can easily become familiar with each technology, its applications and limitations using the section's navigation panels. Indirect reference to the cost of the method is noted for widely used methods in terms of energy requirement, land availability, necessity of maintenance, etc.
3. The design parameters section provides practical information about the range of parameters used in the design of the technologies and in sizing the various tanks/reactors, usually in the form of comprehensive tables.
4. The example section, which is a worked-out example in basic design and sizing each wastewater treatment unit operation. Examples are of great importance for both teaching and learning as they apply and test the theory provided. In this modules examples were taken from working wastewater treatment plants, from real design studies, from textbooks and classroom coursework. The user combines the information from the theoretical part such as mass balances, for example, and the practical information of the design parameters section in order to complete the example.
5. The Excel spreadsheet model, is a design model that solves the example from the previous section in computer form, one for each technology. The model is in a spreadsheet form using the EXCEL program, a form and a software that most students are familiar with. The spreadsheet, which can also be loaded in EXCEL is divided into three sections: a 'nomenclature' section at the beginning, a data section with the given parameters for design and a 'calculations' section where the problem's requirements are displayed. The user is free to modify the selected parameters (data) in the spreadsheet and observe the effect on the units (size, outcome) in order to understand better the operation and the limitations of each process. The user can verify the validity of his/her design and rectify choices in case of failure of compliance by cross-checking with the design parameters. The data used are taken from real design applications or from textbooks, and all parameters, formulas, mass balances, etc. can be found in the theoretical background and in the design parameters section. The user can view the equations in the relevant cells, can save any version of the example and can add additional models if desired. The ambition of this section is to train students in the basic design of a unit operation, but most importantly to allow them to test different scenarios and check the validity of their design. For the tutors it is an important tool in the formulation of appropriate coursework, with staged calculations and freedom to change parameters. As the software allows the user to store versions of the model and to add new models to each technology, students and tutors are encouraged to propagate the exercise.
6. The view section, where the user can find a schematic representation of each technology, view 3D image(s) of each process and also view a full animation with explanatory text showing and describing each process. In most cases 3D images were rendered from digital pictures and engineering drawings, from operating wastewater treatment plants. In animations, the user is taken in a virtual step-by-step walk through each process. Pointers, labels and accompanying text explain the main features of each technology during the show. The animation is split into frames and subframes. The transition from one frame to the next is con-

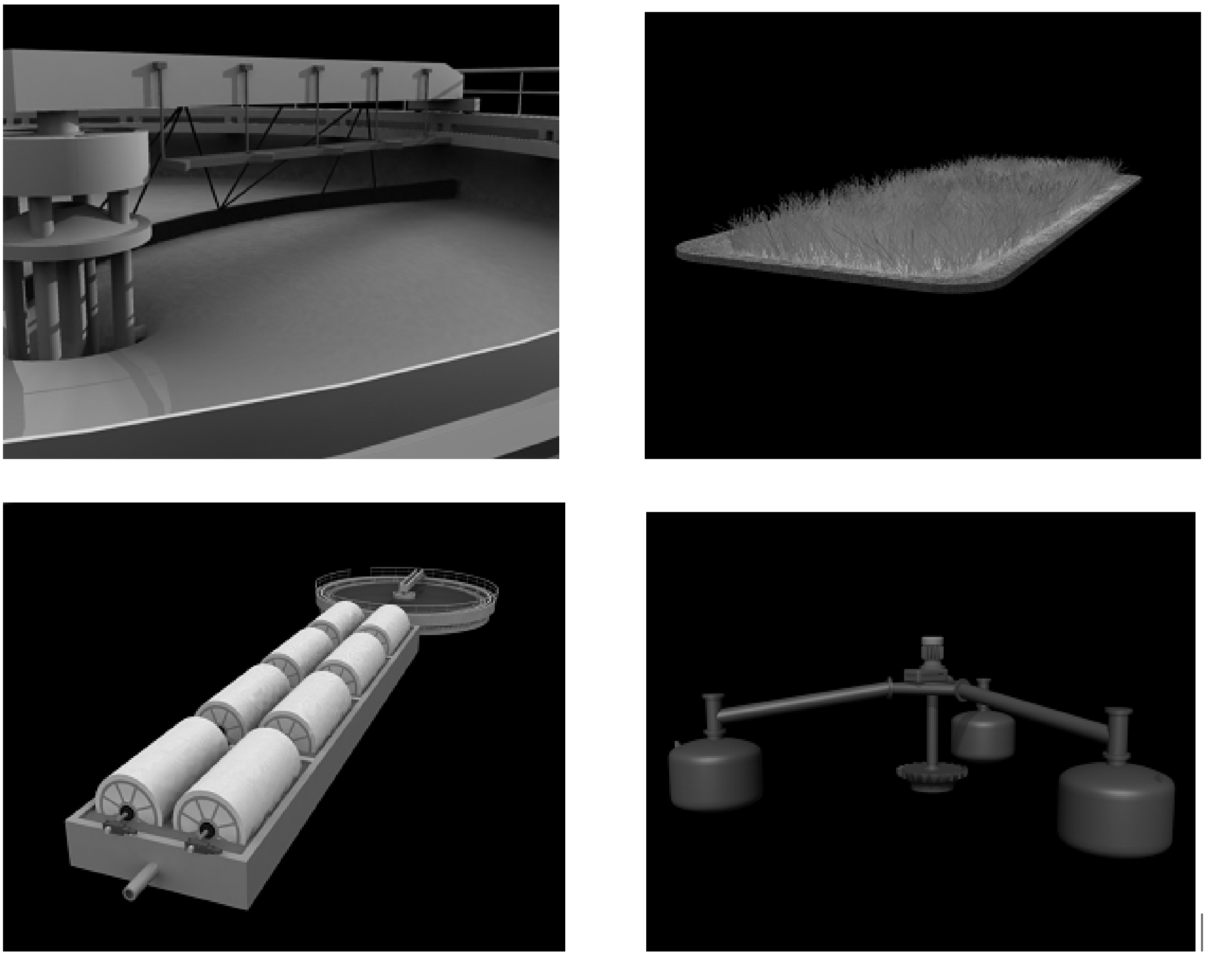

Fig. 1. Top, left: detail of a sedimentation tank. Top, right: general view of a constructed wetland. Bottom, left: general view of a RBC. Bottom, right: detail of a floating aerator.

trolled by a 'forward' button, so the user can regulate the pace of the demonstration. In all animations cross-section views of unit operations allow the user to have an inside view, not visible in a real wastewater treatment plant, visit and observe the phenomena taking place within. The importance of visual media in teaching and training cannot be overstressed. Students and young professionals who have a theoretical knowledge of technologies and processes have seldom had the opportunity to actually see such units in practice. Pilot plant units in laboratories and field visits offer contact with only a limited number of technologies, usually restricted to those applied locally. Moreover, since this is a Europe-Asia cooperation programme, even tutors and experienced professionals haven't had the chance to familiarize themselves with some of the technologies presented. Snapshots from technologies are illustrated in Fig. 1 below and screenshots of the animation of the activated sludge process are presented in Fig. 2 below as an example of the view section.

7. The references section, where the user can find the textbooks used and material for further reading.

The Reference Library is supplemented with a glossary section, where the user can find definitions of terms used in the text of the RL concerning water and wastewater parameters and treatment processes.

Case Study Manager (CM) contains a collection of past wastewater treatment situations based on design experience from real life situations which can be used to solve a new problem specified by the user. The case base of the CM includes a total of 70 case studies obtained from municipal and industrial wastewater treatment plants from Asia and Europe. The industrial sectors include pulp and paper mills, alcohol distilleries, tanneries, rubber and latex processing, textile and garment manufacturing and metal-finishing units.

The CM can take a role of the case base browser, where it gives a user the ability to navigate on cases where professional experience of wastewater treatment is required, and to learn which treatment technologies are usually applied in the selected sectors. The representation of a case

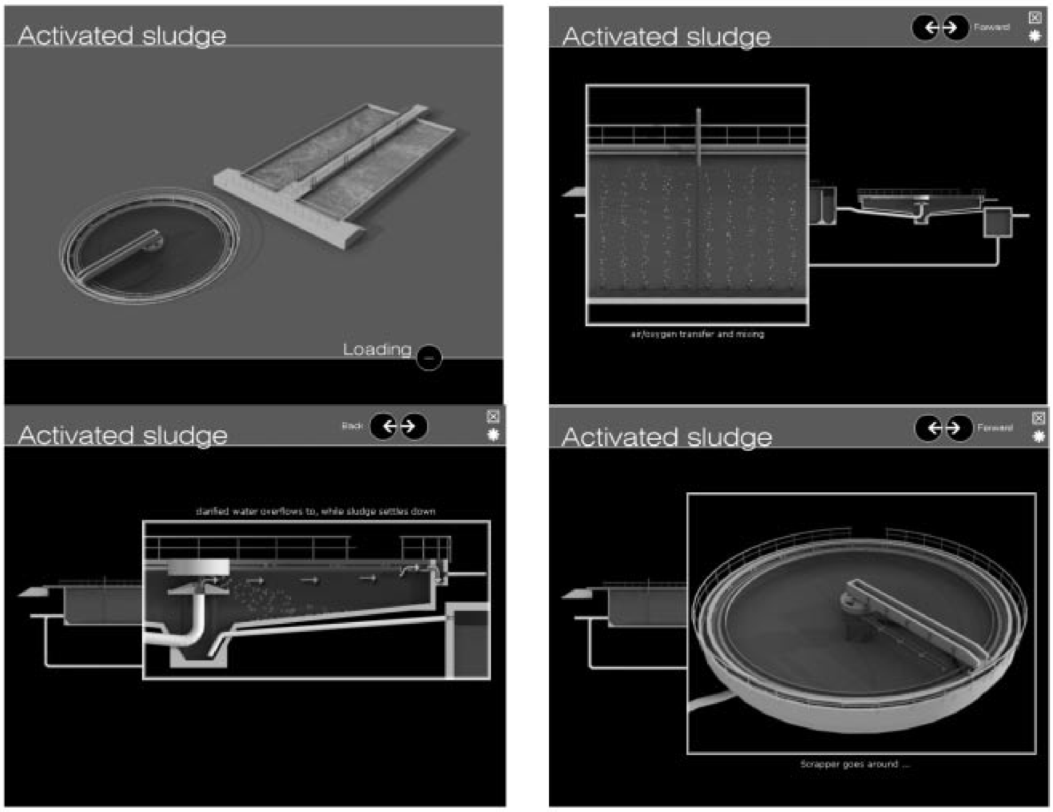

Fig. 2. Different screenshots of the interactive animation for the Activated Sludge process.

includes lists of influent and effluent wastewater characteristics, divided into four groups (physical parameters, organic and inorganic matters and microbiological characteristics), short description of the plant—source of wastewater, average flowrate, the sequence of treatment technologies and additional comments. Also, where available from the industry the cost of treatment per unit volume is included.

The module can also be used to help in solving user problems, either by the user composing a new case study or a problem or by entering influent wastewater characteristics, demanded flow and sector of industry. The task proceeds via dialogue user-orientated interface, step-by- step like 'wizard programmes'. The manager performs the retrieval of cases most like the current problem from the case base by utilizing case-based reasoning (CBR) approach. CBR is based on the assumption that similar problems have similar solutions. A case is represented as a pair: a problem and its solution. In solving a current problem, a similar past problem and its solution are retrieved using a set of rules for measuring similarity between actual problem and those stored in case base [13,14]. The importance of the input parameters for each sector has been weighted. When retrieval is complete the CM provides the user with treatment sequences of similar cases and with a similarity factor (as a percentage), stating the success in finding a similar case. Once relevant cases have been retrieved from the case base, the user can browse through them in order to select the most applicable ones for the current situation.

The module serves the dual aim of first acquainting the user with real wastewater treatment practices in the selected sectors, and then familiarising oneself with parameters of concern and their range in the relevant industry and with the degree of achievement of treatment. The module allows the user to train using real industry data and testing one's own problem and scenario. For maximum involvement and training outcome, the user is allowed to set the weight of the input parameters under instruction of the tutor for a select scenario.

Treatment Adviser (TA) is activated when the user is not satisfied with the solution suggested by CM. Based on an analysis of influent characteristics submitted by the user, the TA generates one or several possible treatment sequences which are then evaluated using data from past applications.

The algorithm of selection is based on the search for deviations in wastewater parameters from normal. The goal is for deviations to be eliminated. Each deviation can be treated by a number of wastewater treatment technologies that are capable to remove (reduce) the contaminant responsible for deviations. The wastewater may contain a number of harmful contaminants that can be processed by many sets of treatment

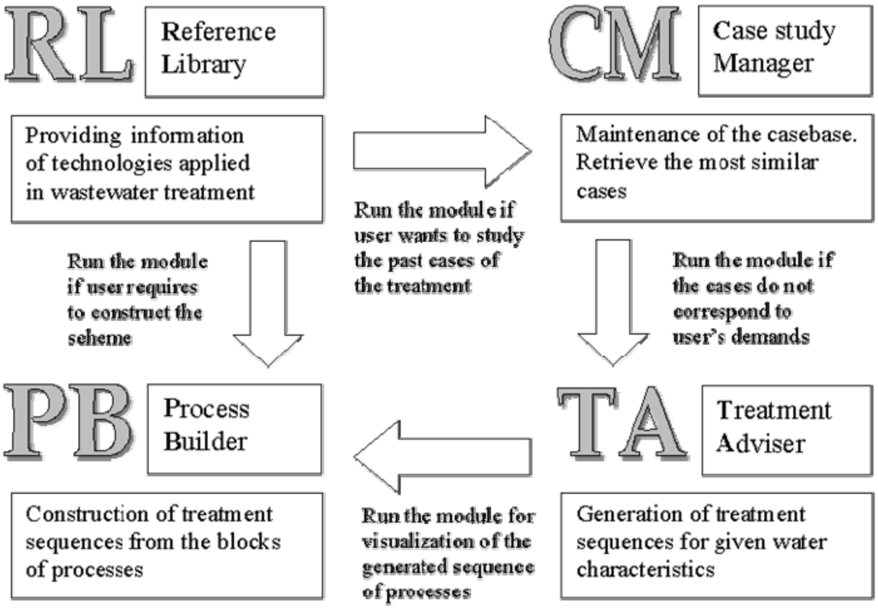

Fig. 3. Schematic of the ED-WAVE software structure.

methods. As a result of analysis, one or several treatment sequences are evaluated by economic and treatment efficiency criteria.

The generated sequences are ranked according to evaluation values gained using data from past applications. The user can browse on these sequences and save the selected treatment to be opened then in the Process Builder as a constructed scheme.

Process Builder (PB) can be used in place of the CM to create and view a valid treatment sequence. The module contains 24 icons (each icon representing one process) that can be dragged, dropped and connected to generate a valid treatment sequence. The module is based on a valid sequence matrix allowing the user to view when a treatment scheme is not feasible. The aim of the module is that the user, after becoming familiar with the concept of the methods and with the practices used in the industry, or with the sequence proposed by the CM, creates one's own wastewater treatment plant, in the form of unit operations blocks. The system accepts treatment sequences by assessing whether two subsequent technologies can be applied or not. The matrix for the permission or the refusal of the sequence is based on technical feasibility only and not on other parameters such as land availability, cost, energy consumption, etc.

The four modules are interconnected and related according to the diagram presented on Fig. 3 below.

PRINTED MATERIAL

As mentioned earlier, the new CD will be incorporated in the curricula of each university, along with printed matter. Courses to incorporate the CD were mentioned above.

The partners of the consortium have formulated the basic structure of courses to be included in the curriculum of each university. The ED-WAVE CD is not stand-alone software. The tutor will have to provide additional material to explain and guide students in decision-making. In these courses, therefore, the CD is going to be the basic learning tool supplemented by printed material, to be prepared under the same project, and regular reading material. The backbone of each of the four developed courses is formulated as follows:

1. *Technologies for efficient water use:* this course covers seven sectors viz. municipal, pulp and paper, textiles and garments, rubber and latex, metal finishing, distillery and tannery. For each sector, the following issues are addressed: (a) Water Use (b) Treatment Technologies (c) Minimization / Recycle / Reuse Options. A total of 10.5 lectures hours is envisaged and will be combined with the exercises on the ED-WAVE tool.
2. *Process selection & modelling of wastewater treatment:* this course with 156 slides is classified in four parts viz. (a) Process selection in wastewater treatment (b) Methods of decision support (using knowledge-based and case-based systems) (c) Introduction in process modelling (d) Modelling of most typical wastewater treatment processes. Part (b) would extensively use the Treatment Adviser (TA) and Case study Manager (CM) from the ED-WAVE tool as examples. Further, Part (d) would use the EXCEL models in the Reference Library (RL) as exercises.
3. *Efficient water & energy use in pulp and paper*

industry: the course material contains 86 slides which cover the topics on (a) Overview of pulp and paper production process (b) Cleaner production concept and methodology for efficient resource use (c) Water usage and efficient water use in pulp and paper industry (d) Energy usage and efficient energy use in pulp and paper industry (e) ED-WAVE tool. The first four topics had already been taught for six hours (in January 2005) in the regular course 200567: 'Cleaner technology and ecodesign' to 19 graduate students majoring in Chemical Engineering, Environmental Engineering and Mechanical Engineering at Kasetsart University. The last topic on ED-WAVE tool was introduced to the students (and also other participants) during the 16th February 2005 workshop in Bangkok.

4. *Computer graphics and new technologies in environment education (UNIZAR)*: the prepared material for this course is of 30 hours duration and consists of two modules. The first module covers Digital Imaging and the second one is about Multimedia Authoring. The theory part is supported by practice exercises. The contents of the course are distributed in Macromedia Director MX slide show format.

DISCUSSION

The first version of this educational CD was presented in 6 training workshops, one in each partners' country, and was evaluated through questionnaires and open discussion by invited academics, graduate and undergraduate students, educators in private and government bodies, professionals working in water and related industries and members of governmental environment boards. Each workshop had an opening session where the CD was presented and a concluding session where the participants dealt with a problem specially formulated for each participant group (i.e. student, academics, professionals, etc.)

The major outcome of the workshops appeared to be the great appreciation of the usefulness of the tool as well as its novelty in environmental engineering education. This is supported by the consolidated feedback from the workshops' questionnaire, which revealed that the tool was overall thought to be of great importance in learning about wastewater treatment technologies, especially for the students. Many participants from academia were also willing to try and incorporate the contents into their own universities. Other comments that came up were suggestions that the tool should be expanded to include more technologies, legislation and trouble shooting modules and an expanded case studies database, points which have been taken into consideration; already many of the comments have been incorporated into the final version.

In the open discussion a point that came up was the change of platform of the tool into an e-learning tool available on the internet instead of the CD form. The argument against it came from the South Asian members, who are a target of this programme, in that power supply is often unreliable and server maintenance erratic, resulting in difficulties involving web-based teaching tools. Moreover, fast internet connections are not so widely spread in individual student's dwellings, whereas, CDs were cheap and could be readily used. It was therefore decided that the final version of the tool should be printed on CD. The tool is also constantly being evaluated by other academia members in relevant conferences and seminars.

The authors believe that ideas in education and knowledge should be available to the widest audience possible and be replicated or adapted to suit particular needs. It is therefore only appropriate that the demo version of the tool should be downloadable (see the project's website at www.ed-wave.org) . The CD itself is also available upon request from the authors (for a limited number of CDs) free to be used as a teaching supplement in any relevant educational course; it is replicable so it can be available to students or interested parties. Moreover, as local and regional necessities or personal data and course line should be respected, it is within the aims of the authors that the software can be enriched or adapted by the user to include more examples, models, case studies and technologies for tailored-made applications.

Acknowledgements—This work has been co-financed by the European Commission Asia Link programme under the project *Education tool for training on technologies for efficient water use using virtual application sites (ED-WAVE)* grant contract ASI/B7–301/98/679–027. The contents of this publication are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union.

REFERENCES

1. Crofton F. S., Educating for sustainability: opportunities in undergraduate engineering, *J. Cleaner Production*, **8**, 2000, 397–405.
2. Boyle C., Education, sustainability and cleaner production-Note from the field, *J. Cleaner Production*, **7**: 1999, 83–87.
3. Painter D. J., Forty-nine shades of green: ecology and sustainability in the academic formation of engineers, *Ecol. Eng.* **20**: 2003, 267–273.
4. Brennecke J. F. and Stadtherr M. A., A course in environmentally conscious chemical process engineering, *Comp.Chem. Eng*. **26**: 2002, 307–318.

5. Gutierrez-Martin F. and Huttenhain S. H., Environmental education : new paradigms and engineering syllabus, *J. Cleaner Production*, **11**: 2003, 247–251.
6. Gutierrez_Martin F. and Dahab M. F., Issues of sustainability and pollution prevention in environmental engineering education, *Water Sci. Tech.*, **38**(11): 1998, 271–278.
7. Kogan M. *et al,* Water for people, water for life—UN WORLD WATER Development Report, UNESCO Publishing, (2000).
8. Zhou Y., Jiang J. J. and Fan S. C., A LabVIEW-based interactive virtual laboratory for electronic engineering education, *Int. J. Eng. Educ.*, **21**(1): 2005, 91–102.
9. Brenner A., Shacham M. and Cutlip M., Applications of mathematical software packages for modeling and simulations in environmental engineering education, *Environ. Mod. Soft.*, **20**: 2005, 1307–1313.
10. Baxter T. E. and Odem O. I., Enhancing Environmental Engineering Education with Multimedia: Case Study of developing and Using A Customized Professional Multimedia CBT Program in Undergraduate Environmental Engineering, Proceedings 2nd International Seminar on Environmental Engineering Education, 24–26 September 2003, Zurich, Switzerland.
11. Schneiter W. R. and Powell B. H., Interactive Spreadsheet-Based Models for Teaching Process Design, Proceedings 2nd International Seminar on Environmental Engineering Education, 24–26 September 2003, Zurich, Switzerland.
12. Oke S. A. Spreadsheets Applications In Engineering Education: A Review, *Int. J. Eng. Educ.*, **20**(6), 2004.
13. A. Aamodt, E. Plaza, Case-based reasoning: foundational issues, methodological variations, and system approaches, *Artificial Intel. Comm.* **7**, 1994, 39–59.
14. Watson I., Applying case-based reasoning: techniques for enterprise systems, Morgan Kaufman Publishers, INC., (1997).

Evan Diamadopoulos is a Professor in the Department of Environmental Engineering at the Technical University of Crete and Director of the Laboratory of Environmental Engineering and Management. He has over 15 years professional and of educational experience with major interests in physical, chemical and biological technologies for water wastewater treatment. He has a doctorate and a master's degree in Chemical Engineering from the McMaster University, Canada and a diploma in Chemical Engineering from the Aristotle University of Thessaloniki, Greece.

Panagiota Paraskeva works as a research associate in the Department of Environmental Engineering at the Technical University of Crete. Her fields of interest are technologies for municipal wastewater treatment and reuse with emphasis on disinfection and ecotoxicity. She has a doctorate and a Masters degree in Environmental Engineering obtained from Imperial College of Science Technology and Medicine, London, UK and a 5-year degree in Chemical Engineering obtained from the National Technical University of Athens, Greece.

Malini Balakrishnan is a Fellow at TERI (The Energy & Resources Institute) and an Adjunct Faculty at the TERI School of Advanced Studies New Delhi, India. She has over 15 years of professional experience, with major interests in development and dissemination of environmentally sound technologies. She obtained her Doctorate in Biochemical Engineering from the Indian Institute of Technology, Master's in chemical engineering from the University of Waterloo, Canada and, a Bachelor's degree in chemical engineering from the Birla Institute of Technology and Science, Pilani, India.

Vidya S Batra is a Fellow at TERI (The Energy & Resources Institute) and an Adjunct Faculty at the TERI School of Advanced Studies New Delhi, India. She has over 10 years of professional experience. Her areas of interest are clean technologies for waste minimization and management. She obtained her doctorate in Materials Science from the University of Cincinnati, USA and her Bachelor's from the Banaras Hindu University, India.

Andrzej Kraslawski, is a professor at Lappeenranta University of Technology, Finland, obtained his M.Sc in 1977 and Ph.D. in 1983 at Institute of Chemical Engineering Technical University of Lodz, Poland. His main areas of interest are knowledge management, data mining, semantic analysis, creativity support in design and hybrid intelligence systems.

Yuri Avramenko, researcher at Lappeenranta University of Technology, Lappeenranta, Finland, received his M.Sc. in 2000 and Ph.D in 2003 at Mendeeleev University of Chemical Technology of Russia, Moscow, Russia. Main trends in research are decision support in design, expert systems, case-based reasoning, methods of artificial intelligence in chemical technology.

Diego Gutiérrez received his B.S. and M.S. degrees in Industrial Engineering in 1996 from the University of Zaragoza, in Spain. He is currently working as an Assistant Professor in the same University. He has finished his Ph.D. in Computer Science, working on global illumination techniques and the generation of synthetic imagery based on the mechanisms of human perception. He has been a member of the Advanced Computer Graphics Group (GIGA) since 1996. His areas of interest include global illumination, computer animation, simulation of natural phenomena and Cultural Heritage.

Oscar Ansón received the B.S. and M.S. degrees in Computer Science Engineering from the University of Zaragoza, Spain, in 2003. He is currently developing his Ph.D. degree and working as an Assistant Professor in the University of Zaragoza. He has been a member of the Advanced Computer Graphics Group (GIGA) since 2003. His research interests include global illumination techniques, simulation of participating media, photorealistic and physically-based rendering and the perception mechanisms of the human visual system.

N. Ratnayake is currently the Head of the Department of Civil Engineering at University of Moratuwa. She has been a lecturer in Environmental Engineering for over 25 years. She is a chartered engineer and a Fellow of the Institution of Engineers, Sri Lanka and a member of the International Water Association, UK. Her areas of interest include Industrial Wastewater Treatment, Municipal Water Supply and Environmental Impact Assessment.

W. Budhikka Gunawarrdana graduated as a civil engineer from University of Moratuwa in 2002 and joined the university staff as a lecturer at the Environmental Engineering Division of the university. She has been working on Ed-WAVE since its inception and has contributed to it in many ways. She has special interests in anaerobic wastewater treatment technologies and is currently reading for an M.Phil. at the university.

Thumrongrut Mungcharoen works as an Assistant Professor for the Kasetsart University in Thailand. He has more than 15 years professional experience with major fields of interest in cleaner technologies and eco design as well as environmental impact assessment , pollution prevention and chemical safety. He has a doctorate and a Master's degree in Chemical Engineering from the University of Texas, USA and a Bachelor's degree (Hons) from the Chulalongkorn University, Thailand.